DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

36-545 MIT, CAMBRIDGE, MASSACHUSETTS 02139

William F. Schreiber
Professor of Electrical Engineering,
Emeritus

DOCKET FILE COPY ORIGINAL

5 August 1996

RECEIVED
AUG 7 1996
FCC MAIL ROOM

Secretary
Federal Communications Commission
1919 M Street, N.W.
Washington, D.C. 20554

RE: MM Docket No. 87-286 168

Dear Sir:

Enclosed is the original and six copies of Part III of my comments in response to the Fifth Further Notice of Proposed Rule Making in the cited docket. The first part of these comments was filed on the 19 June 1996, the second on 10 July 1996. I have also sent copies directly to the Commissioners.

Very truly yours,

W. F. Schreiber

026

Phone: 617-253-2579 FAX: 617-258-7864 E-mail: wfs@image.mit.edu

ORIGINAL

fcc963

Before the Federal Communications Commission
Washington DC 20554

In the Matter of
Advanced Television Systems
and Their Impact upon the
Existing Television Broadcast Service

MM Docket 87-268
Fifth Further Notice of Proposed Rule Making

Reply Comments of

William F. Schreiber
Senior Lecturer, Professor of Electrical Engineering, Emeritus
Research Laboratory of Electronics
Massachusetts Institute of Technology

Submitted 6 August 1996

The opinions in these comments are those of the author only. He has no financial dealings with any computer company. Since his retirement in 1990, the author has had no role in directing MIT's Advanced Television Research Program.

36-545 MIT, Cambridge, Mass. 02139 617 253 2579 wfs@image.mit.edu

Executive Summary

These Reply Comments are directed towards the interlace/progressive issue. It is my opinion, based on many years' experience and study, that interlace is an old idea whose time has come and gone. It has no place in any new television system, particularly in a transmission standard. My previous submissions have gone into this matter in detail.

The superiority of progressive scan and the drawbacks of interlace (including less efficient use of spectrum) are so clear that even the interlace advocates agree that we should migrate to a progressive system eventually, but they maintain that we do not yet know quite how to accomplish this. I have previously gone through the arguments for this position presented by the Grand Alliance; here I deal with the most recent arguments of Sony, which are representative of the positions of most of the Japanese equipment manufacturers. (Matsushita and Ikegami make excellent 525-line progressive cameras.)

A short summary of the history of HDTV development shows that there was a nearly successful effort, supported by a small group of influential American TV interests, to have the NHK 1125-line interlaced system adopted as a worldwide production standard. Fortunately for the US, this effort failed because of European opposition. American industry then went on to develop the all-digital schemes that promise good picture quality and about twice the efficiency of NTSC in the use of broadcast spectrum.

All of Sony's factual statements in support of the use of interlace are faulty. These include such notions as the idea that interlaced pictures have better quality than progressive pictures at the same digitally coded data rate. This was shown not to be true in ATTC tests. Sony also ignores the well-established fact that *interlaced and progressive signals having the same number of pixels per frame and the same number of fields per second require the same coded date rate, even though the latter has twice the analog bandwith.* Sincere support for the use of interlace under these conditions would be perverse. Sony also attempts to downplay the significance of the Polaroid progressive camera, the development of which they had said was many years away.

The Sony opinions offered in support of their position are even further away from reality. They suggest that we should use interlace because all current systems do so, and because the "best minds" in the industry are in favor of interlace. This should not be viewed as a controversy between the TV industry and the computer industry. While the latter is unanimously opposed to the use of interlace, the TV industry is divided. Two of the four TV networks favor progressive scan, and the cable industry is opposed to the entire Grand Alliance standard. Incredibly, Sony gives as another reason for using interlace the fact that Sony and other Japanese companies have made a "huge" investment in interlaced production equipment.

There is no possible advantage to any domestic stakeholder in the use of interlaced transmission, and there are many disadvantages, such as inhibiting the migration to progressive. Progressive transmission offers higher quality, more efficient use of spectrum, and easier transcoding. The production standard adopted in the US ought to be in the public interest in this country. It need not take into account that foreign manufacturers have an investment in a different technology.

1. Introduction

These Reply Comments are directed toward the interlace/progressive issue. Since Sony is the most important corporation proposing that interlaced (I) transmission be permitted in addition to progressive (P) transmission, and since Sony's Comments exemplify many of the arguments that are now being made, I have dealt in this paper only with the Sony submission. Similar arguments would apply to the submissions of most other parties holding similar opinions.

In making its decision in this case, I trust that the Commission will keep in mind the history of this Inquiry, starting with its inception in 1987. At first, its purpose was to assess the effects of the Japanese HDTV developments on the domestic broadcasting industry. The purpose then shifted to setting standards for high-definition terrestrial broadcasting. At that time, most American TV interests favored a system that would be compatible with NTSC, modeled on the means by which NTSC color was added to the existing NTSC monochrome system in 1953. At the same time, a small but influential group within the broadcasting industry was making a nearly successful attempt to have the NHK 1125-line interlaced system adopted as a world-wide production standard. This effort was so effective that the State Department was persuaded to advocate this system in international meetings, much to the dismay of our European allies. If adopted, this proposal would have given an overwhelming advantage to the MUSE transmission system, even though that system was developed for satellite transmission.

The effort finally failed, mainly due to European opposition. In the meantime, the Inquiry stimulated HDTV development in the US. Many proposals were made, primarily for analog systems, most of which were NTSC-compatible. In 1988, a fundamental shift took place when Zenith announced a noncompatible hybrid analog/digital system said to be capable of using the taboo channels. NTSC receivers would be served by simulcasting in the original channels that were already in use, and, eventually, NTSC would be abandoned. (This was the scenario used in France and Britain after PAL was introduced in 1965.)

The Inquiry was fully turned around in 1990 with the proposal by the General Instrument Corporation for an all-digital system. GI showed that high-quality images could be produced, even at very high compression ratios, so that the required data rate might well be accommodated with the 6-MHz broadcast channel. Simulcasting would be used to serve existing receivers, just as in the Zenith scheme. Soon, all the American proposals shifted to the all-digital model.

The Japanese persisted with their analog system, although it was now at a severe disadvantage because analog methods simply cannot achieve as high a compression ratio as digital methods that involve the transmission of at least some digital data in the channel. When the first testing took place at ATTC, the four digital systems performed much better than MUSE or ACTV, the American compatible system, and both of the latter were withdrawn. Nevertheless, MUSE is on the air in Japan on a regular basis, although no mass market has developed for the receivers.

Most people failed to notice that the version of MUSE tested by ATTC performed very much better that expected, in view of a compression ratio much lower than that of the digital systems. This is due

to excellent work by NHK engineers and due to the fact that MUSE makes very efficient use of the broadcast spectrum.

Japanese determination to develop and implement MUSE commercially led to the development of a full line of production equipment by Sony and other Japanese companies. With the obvious superiority of the all-digital systems, these companies cannot possibly have hoped that MUSE would be adopted anywhere else. In fact, it is likely that MUSE will die in Japan as soon as politically acceptable. The money spent to develop MUSE receivers is lost forever, but the money spent to develop studio equipment might still turn out to have been well invested should the 1125-line I system be adopted as a production standard. My opinion is that this hope is the main force behind the push to use interlace in digital broadcasting in the US.

The Comments made by Sony in this proceeding are essentially the same as the arguments presented in 1993 to the ATSC T4 Focus Group on the Interlace/Progressive Issue. (Sony is no longer claiming a large economic advantage for interlace.) However, two important developments have occurred since that time. One is that it has been established that *an I signal and a P signal having the same number of pixels per frame and the same number of fields per second require the* same *digital data rate when encoded by MPEG,* even though the former has twice the analog bandwidth as the latter. The other is that a fully operational P camera has been developed by Polaroid, in spite of the fact that 1125 advocates had claimed that this development was far in the future. Sony has ignored the first development in its Comments and has tried to show that the second development is of no importance.

Ironically, even if the Commission decides not to include I formats in the coming standard, Japanese companies are still likely to dominate the market for professional equipment. They will, of course, have to modify their 1125 I products. As shown by the successful conversion of a 1250 I camera to 720 P by Polaroid and Philips, this is quite practical and will not cost an exorbitant amount of money.

The advantages of a progressive system over an interlaced system are so large that even the I advocates have had to admit that eventually, broadcasting should migrate to a progressive system. The main claim is that we don't quite know how to do this at present. The P advocates, such as the computer industry and myself, have pointed out that the existence of a substantial number of I receivers is likely to present a backward-compatibility obstacle to migration to a P system. We fear that if any interlaced transmission is allowed, we will never move to progressive, and we shall be stuck for decades with a system that, among other things, does not make most efficient use of spectrum. The detailed arguments are presented in my submissions of 11 March 1996, 14 June 1996, and 10 July 1996. *I believe that these arguments clearly demonstrate that, except for 1125 I equipment manufacturers, interlaced transmission offers no advantage of any kind to any of the stakeholders.* In the last of these submissions, I have presented a proposal for changes in the Grand Alliance system that would cost almost nothing, yet would go a long way towards satisfying both the TV and the computer industries. Copies of these submissions can be had by sending e-mail to dmanning@image.mit.edu, or by calling me at 617-253-2579.

In Section 2 of this paper, the objections to permitting interlaced transmission are summarized. Section 3 deals with factual issues in the Sony Comments, while Section 4 deals with opinion issues. Conclusions are presented in Section 5.

2. What is Objectionable About Interlaced Transmission?

This material is dealt with in detail in my above-cited earlier submissions, which include copies of a number of original papers by various authors on the subject For the convenience of readers, a short summary is presented at this point.

Many regard interlace as a bandwidth-conservation technique that can be thought of either as doubling the large-area flicker frequency without loss of vertical resolution, or doubling the vertical resolution with a given horizontal scan rate. The improvement actually achieved is closer to 10% than to 100% under normal operating conditions. Attempts to achieve a vertical resolution equivalent to the number of lines per frame produces absolutely intolerable interline flicker in detailed areas of the image This is the reason why computer displays are now invariably progressively scanned.

The slight improvement in vertical resolution brings with it other serious image impairments, such as excessive "jaggies" along edges that are nearly horizontal, poor rendition of fine detail such as text, as well as image breakup and catastrophic loss of vertical resolution with vertical camera motion. Finally, with interlace, transcoding between two different scanning formats becomes both expensive and of poor quality. This is typified by the defects of NTSC/PAL conversion, a process still not entirely satisfactory even after decades of attempts

It is often said that, even though quality is admittedly impaired with interlaced transmission, viewers don't mind since they are more interested in program content than in technical image quality. Of course, this is true, but it is irrelevant. When the Commission decides on the channel capacity (bandwidth or data rate) to be used for TV transmission, it is trading off image quality against the amount of spectrum that must be allocated to give viewers a given number of program choices. Systems that do not give the highest possible quality within a given channel capacity waste spectrum, a resource that is strictly limited in quantity.

If a substantial population of interlaced receivers comes into existence because of interlaced transmission, then the promised migration to progressive scan is likely never to take place. The reason for this is that later progressive transmissions will have higher vertical resolution (without this, there is not much reason to make the change) and will cause very bothersome flicker on the interlaced receivers. Avoiding this problem requires strict regulation of receiver characteristics or a day-one determination of just how the migration is to take place Historically, the Commission has been very reluctant to take these kinds of actions, and presumably it is still of this view in today's deregulatory environment.

One of the arguments often used by interlace advocates is that it permits the manufacture of cheaper receivers. As I have pointed out elsewhere, I receivers can readily be used with P broadcasting at no increase in cost. NTSC material can still be transmitted in the P format by transcoding, the cost of which is negligible compared to the cost of converting to digital transmission. *Valid as the arguments that I have presented are, they really are not needed because there is no advantage to any stakeholder except foreign equipment manufacturers if interlaced transmission is permitted.*

3. Statements of Fact in the Sony Submission

`Production, transmission, and display formats need not be identical in an all-digital system because high-quality transcoding is easy.`

To the extent that this is true, it is also true for analog systems, even though the required signal processing would normally be done digitally. In fact, it is not so easy to transcode from interlaced systems, as evidenced by the defects seen even today in PAL/NTSC conversion. Sophisticated motion-compensated conversion is practical for use at the encoder, but it can be used only in very expensive receivers. If it were really true that transcoding were so simple, then the camera would not be an issue at all, since an interlaced camera could readily be used with progressive transmission.

`Interlace works. It is the only way to get full 1080x1920 spatial resolution. (This statement is repeated many times in the submission.)`

Interlace can be thought of either as trying to double the large-area flicker rate for a given bandwidth or trying to double the vertical resolution for a given horizontal scan rate. From the second point of view, it was shown in 1966 by E.F.Brown of Bell Laboratories that the vertical resolution is raised only about 10% at normal brightness. Vertical resolution of 1080 lines in a 1080 I system is possible only with still images, with very careful filtering, and with the camera in the "frame-integration" mode, which precludes its use for motion. Even then, interline flicker would be intolerable unless a progressive display were used. Typically, the effective vertical resolution of an I system is equal to that of a P system with 60% as many scan lines.

`1920x1080 I gives better pictures than 1280x720 P`

This is entirely untrue. A comparison of these two formats was done by ATTC in the course of the testing process. The overall subjective quality of the two systems at the same digital data rate was about equal, even though the P signal was down-converted from 1125 I and so wasted a part of the vertical definition of the 720 P system. The objectively measured vertical resolution of the 720 P system was higher than that of the 1080 I system. In general, when comparing I and P systems having the same number of lines per frame, the P system will have 60-70% higher vertical resolution.

`It is impossible at present to transmit 1920x1080 P in 6 MHz.`

This is not quite true. It is possible if the SNR is high enough, which is the case in both cable and DBS. (Note that cable interests are against the entire Grand Alliance system.) In terrestrial broadcasting, the downtown channel capacity is typically four to five times as high as at the boundary of service, so that the data rate in those areas could be increased by that amount, which is surely enough for 1920x1080 P. A multiresolution ("layered") system in which receivers recover a variable amount of data depending on the signal quality, can readily do this. My students and I have simulated just such a system at MIT.

`Most I artifacts can be cured by de-interlacing at the receiver and using a P display.`

It is true that with a sufficiently complex (and costly) motion-compensated de-interlacer, interline flicker can be reduced, at least for still images. (A simple-minded de-interlacer based on linear filtering would give much poorer results.) However, edge artifacts and image breakup with vertical camera motion will still be present. We must also not neglect the transcoding cost. High-cost equipment is tolerable at the encoder, but receivers are very price-sensitive. At the same frame rate, P-to-P and P-to-I transcoding are cheap, but I-to-P and I-to-I transcoding are expensive.

"Progressive scanning does not come for free...the television engineer is confronted by...constraints that directly relate to bandwidth (and its associated digital data rate.)"

It is true that an analog P signal has twice the bandwidth as an analog I signal with the same number of pixels per frame. However, the coded data rate is the same, even though the quality of the decoded P signal is much higher. This well established fact, which is of the utmost importance in choosing transmission standards, appears nowhere in the Sony document.

The recently announced Polaroid P camera is no good because it has 1.5 stops lower sensitivity than the Sony I camera.

Even if the stated difference in sensitivity is accurate, the comparison is meaningless, since the real issue is whether the camera has adequate sensitivity for its intended applications. According to Sony, the Polaroid P camera has a SNR of 50 dB as compared with 54 dB for the latest Sony I camera. Any HDTV camera has a sensitivity at least 12 dB less than that of a comparable NTSC camera. Presumably Sony would not therefore say that all HDTV cameras were useless. It should be noted that Sony was pushing the 1125 I system at a time when its HDTV tube camera had a SNR of only 43 dB. (The pictures were actually quite good.) I have seen the Polaroid camera operate in a very dark room, and I am convinced that it does have fully adequate sensitivity.

In Sony's discussion of the Polaroid camera (pp 16-18) it is not always clear whether they are comparing their latest 1920x1035 I camera to a theoretical 1920x1035 P camera or to the actual Polaroid 1280x720 P camera. The fundamental limitation on SNR in TV cameras is set by the number of photons collected per pixel and the number of pixels read out per second. On this basis, an NTSC camera, with four times the photons per pixel and one-quarter the bandwidth as a comparable HDTV camera, would have a theoretical SNR 12 dB higher. When comparing a P with an I camera with the same number of pixels per frame, the P camera suffers a 6 dB noise penalty. (The oft-quoted 9 dB difference is for tube cameras with a triangular noise spectrum.)

The Polaroid P camera has a rate of 55.3 Megapixels/sec, while the Sony I camera has a rate of 59.6 Megapixels/sec. Thus their theoretical limiting SNRs are about the same. While there are some practical engineering differences between the P and the I cameras, there is no fundamental reason why the P structure, which is actually simpler, should give a lower SNR. I am quite sure that the reason why Sony has not yet delivered a good P camera is not that it will take their highly qualified engineers ten years to figure out how to do it, but that, for business reasons, they don't want to.

Sony gives sports events and theatrical performances as examples of low-level lighting where higher camera sensitivity is useful. In these situations, there is always adequate illumination. The main

application for very low-light-level video capture is in electronic news gathering (ENG). At the current state of the art, I do not envision reporters carrying any kind of HDTV camera for this purpose, as the cameras are simply too big. One of the good features of the Grand Alliance system is that it can utilize standard-definition input, as it is highly likely to do in just those situations where lighting is insufficient.

`Noise reduces the quality of compressed images.`

This is a similar argument to the low-light case above. It is quite clear that no broadcaster is going to transmit only HDTV signals when the DTV system goes on the air. HDTV will be reserved for those situations in which its special characteristics of high detail resolution and a wide field of view will give a different kind of viewing experience than we get with NTSC. Standard definition will be used for many kinds of programs, including those in which a good quality image cannot be obtained.

4. Statements of Opinion in the Sony Submission

`Anyone who doesn't agree with Sony is confused`

In my opinion, those who oppose the use of interlace transmission are not at all confused. By now, virtually everyone who is following the FCC process has been educated as to the fundamental issues of TV broadcasting. The problem in reaching consensus is that most participants in the FCC process are employees of companies that think they know where their interests lie. In that case, it would be a rare employee who would go to Washington and voice opinions contrary to those of his employer. This same phenomenon has produced a situation where almost no one changes his "opinion" as a result of discussion.

`Only the computer people are against interlace.`

This is just not so. ABC and Fox -- two of the four networks -- prefer progressive scan. On the other hand, the computer people are unanimously against interlace; there is not one dissenting voice. For what it is worth, I consider myself a TV person (I am not now and never have been in the pay of any computer company) and I believe that interlace has no useful role in new TV systems.

`All current TV systems use interlace.`

This is certainly true; it is also true that there was a time when all vehicles were propelled by animals.

`All the best technical minds in TV want to use interlace.`

This is not true; as pointed out above, two of the four TV networks favor progressive scan. It is worth noting that almost all these "best minds" at one time wanted HDTV to be compatible with NTSC. At another time, almost all the best minds thought the earth was flat.

`"There is little to gain by any adoption of a dogmatic stance that seeks to rigidly impress the technical views of one industry on another..."`

Isn't that exactly what Sony is trying to do in this submission? My opinion is that there is no advantage to any stakeholder in using interlaced transmission, except to foreign manufacturers of 1125 I production equipment. What happened in the Grand Alliance is that no system proponent was willing to give up his favorite format completely, so that both I and P formats are in the proposed standard. What is really remarkable is that the two interlaced formats (960 lines and 1050 lines at the time of testing) were changed in a way that miraculously made the 1125 I system the production standard.

`The GA system is a consensus standard.`

The computer industry, which has been against interlace from the start, simply got outvoted, as did the progressive scan advocates within the television industry

`Sony has made "huge investments" in interlaced systems and is developing a new line of cost-effective production equipment.`

A little perspective is needed here. It costs Detroit about $1B to get out a new car model -- $4B for the Saturn -- whereas total worldwide spending on ATV by all entities involved is probably less than $1B. As I have pointed out in previous submissions, there is no advantage, financial or other, to any TV stakeholder in the use of interlaced transmission, except to the manufacturers of 1125-line I production equipment, all of which are foreign-owned. On the other hand, there are many disadvantages that come with I transmission, not only to TV, but also to the computer industry, which is unanimously opposed to the use of interlace. There is no reason why an American standard should be set that disadvantages a large American industry while giving advantages to a foreign-owned industry. Ironically, if the Commission decides that interlace is not to be used in the DTV standard, I predict that foreign manufacturers such as Sony will shortly thereafter announce their P equipment and will end up getting most of the market.

5. Conclusion

In my submission of 11 March 1996, I believe that I showed that the reasons given in the Grand Alliance Reply Comments of 22 January for using interlace were erroneous. In this submission, I have tried to do the same for the more recent Comments of the Sony Corporation.

In its Comments, Sony has made a series of factual statements and has given a series of opinions, all to the effect that interlaced transmission is beneficial -- indeed essential -- if digital broadcasting is to take off promptly with the expected issuance of a standard by the Commission. The "facts" include statements to the effect that interlace works, interlaced pictures of the same coded data rate are better than progressive pictures, 1920x1080 P cannot be transmitted in 6 MHz, most interlace artifacts can be eliminated in the receiver, the Polaroid progressive camera is inadequate, and that progressive scanning presents great obstacles to the work of TV engineers. Every one of these "facts" is incorrect.

Remarkable as is this series of factually incorrect statements, the vacuity of Sony's position is best illustrated in its statements of opinion. Those who don't agree with Sony are confused, only computer people are against interlace, all current systems use interlace, all the best technical minds favor interlace, and the GA system is a consensus standard. As if this were not enough, Sony then goes on to

say that there is little to gain from a dogmatic stance that seeks to impose one industry's views on another, as if that is not exactly what Sony is trying to do.

Sony was once one of my sponsors at MIT. I know many Sony engineers and executives quite well, and have a very high opinion of their collective competence. It is therefore with deep personal regret that I am inescapably led to the conclusion that these erroneous statements cannot be simple errors. On the contrary, I believe that the most likely reason for Sony's position is revealed in its final comment. Sony and others have made "huge decade-long investments" and "a new generation of cost-effective HDTV studio equipment based initially on interlaced scanning" is being developed. That Sony wants to recoup its "huge...investment" is perfectly proper. However, in setting a standard for the US, it is not incumbent on us to take this into account. A standard is needed that meets the needs of American stakeholders and is in the public interest in this country. Interlace, a very old idea whose time has come and gone, has no place in such a standard.